Humanoid Robotics for Patients with Sarcopenia: A Preliminary Study on Interaction Features

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Abstract A significant growth of the population of senior citizens is estimated to be observed in the coming years, leading to the onset of socio-sanitary issues. Therefore, it is important to design tools that facilitate active ageing and prevent the occurrence of physical frailty in older people, making seniority a valuable resource rather than an issue of concern. Technology represents an efficient tool to take on such task, as it facilitates the replicability of human-centered trials. In particular, humanoid robotics have proven to be effective applied to weak users, notably in the treatment of people with cognitive disorders, both children (e.g. autistic) and older patients (e.g. Alzheimer). Humanoid robots could represent efficient tools in the design of trials to promote active ageing, since the latter are able to guide elderly people through exercises, to monitor proper execution and to give a real-time human-like feedback, with a consequent involvement of the users. Such high-level of engagement characterizes that kind of interactions, called Human-Humanoid interactions, which should be invested of the same importance of morphological and technological aspects during the design phases. In this paper we provide an overview of some humanoid robots which have been used over the last years in the revolutionary robotics field, providing a comparison of the principal interaction features in relation to what kind of user every robot was designed for.

Such preliminary study will serve as a basis to define the most appropriate aesthetic/behavioural features required in the design of a humanoid robot for the prevention of sarcopenia.

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1 Introduction

The European Union estimates that a significant growth of the population of senior citizens will be observed in the coming years. Such increase will rise social costs for the active population, which will decrease in the meanwhile.

With regard to clinical issues that affect older people, it can be stated that frailty is one of the most significant disease, as it can determine the occurrence of obesity, depression, risk of falls, and many others [1]. Frailty is a disorder that usually emerges from the sixtieth year of life, due to the loss of physical and psychological abilities, and involving loss of muscle tone, mass, and strength. The incidence of this latter condition, known as "sarcopenia", is expected to dramatically increase in the next 30 years [2].

Physical activity is essential for preventing physical and cognitive decline. Therefore, tools that facilitate active ageing are expected to prevent socio-sanitary issues and help in making seniority a valuable resource rather than an issue of concern.

Technology represents one of the more efficient tools to take on such task, as it facilitates the replicability of human-centered trials. In particular, there is a technology field in which several studies have been carried out in recent years and that seems very promising for the future of research: humanoid robotics.

A study carried out by the Architecture and Design Department of the University of Genoa is investigating the use of a humanoid robot, Pepper, as a tutor in training sessions for elderly in order to prevent sarcopenia. In this paper we analyse and compare proprieties and features of different humanoid robots, in order to highlight which of them are suitable for the design of a humanoid robot to be used in the prevention of sarcopenia.

2 Humanoid Robotics

Humanoids are robots which are chiefly humanlike in their morphology and behaviour. Eaton [3] outline a detailed taxonomy for n + 1 separate levels of embodied humanoid.

0 Replicant. Looks exactly like a human being in terms of physical aspect and behavior.

1 Android. Very close to human morphology and behavior. Difficult to distinguish from a human.

n – 3 Humanoid. Close to a human with high levels of intelligence and dexterity. However, there is no possibility of mistaking the robot for a human being.

n – 2 Inferior Humanoid. Has the broad morphology of humans and a reasonable intelligence but may be confined mainly to a limited task set.

n – 1 Human-Inspired. Looks quite unlike a human but has the broad morphology of humans. It may have bipedal capabilities or be wheeled. Limited intelligence and dexterity.

n Built-for-Human. Looks nothing like a human but it is able to operate in most human-centered, designed environments [4].

3 Humanoid Robotics Application

Generally speaking, humanoid robots can find application in different contexts, such as:

- Work dangerous for humans
- Works which humans normally find unpleasant or tedious
- Home assistance
- Care of weak users
- Entertainment

Since many robots in scientific fictions look like humans, in the collective unconscious robots are humanoids by default. Actually, thanks to advancing technology, there has been the trend to design robots increasingly humanlike, triggering the so-called uncanny valley effect [5].

However, with regards to the first two categories described above, a robot designed to operate in industrial workspace should not be humanlike for any practical purpose. Nevertheless, we are seeing an increasing trend of anthropomorphic design of CoBots. It seems clear that at least some humanoids features are always preferred in the design of a machine bond to work at the side of a human.

In respect of the home assistance field, apart from virtual assistants like Amazon Alexa or Google Home, humanoid shapes are unavoidable for a humanoid robot aimed at helping people in physical tasks. In fact, in this case both the environment and the tools are human-centered designed. The width of a corridor, the height of a stair, the size and shape of chairs and tables are all designed by referring to ergonomic standards. Therefore, it should be more economical and reasonable to use humanoid robots whose design is based on these standards than to re-design environments and tools [6]. Moreover, caregiving and entertainment represent areas in which humanoid robotics proves to be more efficient due to the high level of engagement with the user [7].

4 Humanoid Robotics for Sarcopenia Prevention

As stated before, humanoid robotics has been successful in interacting with weak users for entertainment purposes [8]. Moreover, studies have shown that humanoid robots are able to increase the users' propensity for imitation [9].

With regard to the healthcare area, humanoid robots have proven to be particularly successful when employed in the treatment of people with cognitive disorders, either in the case of children (e.g. autistic [10, 11]) or older patients (e.g. Alzheimer [7]).

Based on these data, it can be assumed that humanoid robotics could represent an efficient tool in the design of trials to prevent sarcopenia. Since physical activity plays a key role in active ageing, such trials could consist of sessions of physical activity tutored by a humanoid robot. The robot will be able to guide users through exercises, to monitor proper execution, and to give a real-time, human-like feedback.

These aspects are related to Human–Robot Interaction (HRI), which is the key for the success of every application of Humanoid Robotics. Indeed, we can, de facto, consider robots as technological industrial products with the highest possible level of interaction (if we assume human–human interaction as the best interaction possible). Thus, we assume that the design of such interaction should have the same importance of morphological and technological aspects.

Therefore, the design of a humanoid robot requires a highly interdisciplinary approach, with contributions from such different fields as engineering and industrial design, psychology and medicine, philosophy and ethics. The role of the designer is to take into account interactions as the key factor in every choice during the development of a humanoid robot.

5 Brief Overview of Selected Humanoid Robots

In this section we provide an overview of some humanoid robots which have been used over the last years in the revolutionary robotics field. Because of the large and ever-growing number of humanoid robots under development and in use, we will focus mainly on robots available on the market, plus some interesting case studies.

In the table (Table 1) we analyze the main properties and features of twenty humanoid robots divided by price range: less than 2000 €, between 2000 € and 20,000 € and more than 20,000 €. Humanoid robotics is a relatively new and unregulated field, therefore, instead of spotlighting a precise range, it is likely to be more useful to focus on the entire panorama of products, looking for features in common between robots from different price ranges. Additionally, the infographic (Table 2) provides an overview of the main interaction features in relation to what kind of user every robot was designed for.

6 Conclusion

The analysis has highlighted some interesting cues for the design of a humanoid robot for patients with sarcopenia. First, it appears that white is the most common colour used for the covers. Some other colours are used for the inserts. It is found that grey and light blue are the most common second colours for robots designed

Table 1 Main properties and features

Name	Manufactures	Country	Price (€)	Year[a]	Height (cm)	Weight (kg)	Special features
Pando	Leju Robot	CHN	300	2018	35	1,5	Cartoon-like
Little Sophia	Hanson Robotics	HKG	300	2019	35	–	Human-like woman face
Kirobo Mini	Toyota	JPN	350	2017	10	0,2	Cartoon-like
Alpha 1 Pro	Ubtech	CHN	650	2016	40	1,6	Cartoon-like
Aelos	Leju Robot	CHN	700	2018	34	1,6	Cartoon-like
Walker	Ubtech	CHN	1000	2019	140	77	
Ipal	Avatarmind	CHN	2000	2015	103	12,5	
R1	IIT	ITA	3500	2019	145	50	
Zeno	Robokind	USA	4600	2007	56	–	Human-like face
Iuro	ACCREA	POL	5000	2012	169	200	
Nao	Softbank Robotics	JPN	7000	2004	58	4,3	Children-like
Poppy	Inria	FRA	8800	2012	85	3,5	3d printed
Sanbot	Qihan Technology	CHN	9000	2016	92	19	
Robotis OP3	Robotis	KOR	11,000	2017	51	3,5	
Pepper	Softbank Robotics	JPN	20,000	2014	120	28	
Asimo	Honda	JPN	15,000	2000	130	48	
Atlas	Boston Dynamics	USA	200,000	2013	150	75	
iCub	IIT	ITA	250,000	2009	104	22	Children-like
Romeo	Softbank Robotics	JPN	250,000	2019	146	36	
Talos	Pal Robotics	ESP	900,000	2016	175	95	

[a]Year of the first production

without a precise category of end-users. In the industrial field orange is also often used, if we consider co-bots that are not in this analysis.[1]

With regard to robots designed for children or weak users, there is evidence of a wider use of colours as blue and red, and specifically pink for products targeted to girls. Moreover, robots designed for children seem to be inspired more closely by

[1]Reference is made to co-bots by companies as Hanwha, Kuka and Aubo.

Table 2 Interaction features

Price range	Robot	DOF	Human-likeness	Colours	Legs	Arms	Eyes	Vocal interaction	Motor interaction	Multimedia support	Weak end-users
100€ – 2.000€	Pando	6	n-1		●	●			●	●	●
	Little Sophia	-	n-2		●	●	●	●	●	●	●
	Kirobo Mini	-	n-1		●	●	●	●	●		
	Alpha 1 Pro	16	n-1		●	●	●			●	●
	Aelos	16	n-1		●	●				●	●
	Walker	19	n-1		●	●		●	●		
	Ipal	24	n-1		●	●	●	●	●	●	●
2.000€ – 20.000€	R1	28	n-1			●		●	●		
	Zeno	21	n-2		●	●	●	●	●		●
	Iuro	21	n-1			●	●	●	●	●	
	Nao	24	n-1		●	●	●	●	●		●
	Poppy	25	n-1		●	●					●
	Sanbot	6	n-1			●		●	●	●	
	Robotis OP3	20	n-1		●	●	●				●
	Pepper	14	n-1			●	●	●	●	●	●
20.000€ – 200.000€	Asimo	32	n-1		●	●					
	Atlas	28	n-1		●	●			●		
	ICub	53	n-1		●	●	●	●	●		
	Romeo	37	n-1		●	●	●	●	●		●
	Talos	32	n-1		●	●					

cartoon characters than by human morphology. Therefore, a distinction can be made between human-like robots (normally called humanoids) and cartoon-like robots.

For what concern the limbs, arms seem to be essential to ensure a perception of the robot as a humanoid. The same importance is not given to legs, although this may be due to technological reasons instead than aesthetic choices.

Contrary to what we might have expected, it appears that a human-like face is not an essential feature. Many designers chose to have lights and screens as a replacement for eyes, mouth, eyebrow or the entire face. It is well known that people tend to see human face in inanimate objects. Maybe this ability is so well-developed that is not necessary to pursue a high level of human-likeness in the design of the head of a humanoid robot.

An additional device as a tablet placed on the chest of the robot turns out to be a useful feature, as well as the possibility of connecting the robot with a mobile app.

With regard to size, robots designed for children or, generally, with recreational purposes are often shorter than 1 m. Humanoid robots designed for elderly are usually taller than 1 m but still shorter than those who are not designed for a specific end user.

It is interesting to note that, with respect to the taxonomy set out above, delineated by Eaton [3], almost all humanoid robots taken into account belong to the $\mathbf{n-1}$ level. However, the level of human likeness is very different among them. Therefore, it would be appropriate to outline a sub-division of the $\mathbf{n-1}$ level.

The possibility of having vocal and physical interactions depends mostly by the budget of software development, so it can be argued that the higher is the price of the robot, the better is its capability of interaction. Since costs are always a key variable, the right solution is generally the one that maximizes goal achievement without wasting economic resources.

This overview has provided useful findings for the design of a humanoid robot for the prevention of sarcopenia. Nevertheless, the actual deployment of the robot will dictate the design choices. As the prevention of frailty needs physical activity, it can be expected that such robot will become a sort of trainer for old people. A trial led by *the Architecture and Design Department* of the *University of Genoa* and the *Hospital of national importance and high specialization Galliera* of Genoa is investigating the use of the humanoid robot Pepper as a tutor for physical activity sessions with sarcopenic and pre-sarcopenic users.

Future studies will investigate how the robot behaviour, and other features like volume of speech and speed of movement, can affect the human-humanoid interaction.

References

1. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, ... Schols J (2019) Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 48(1):16–31. https://doi.org/10.1093/ageing/afy169
2. Ethgen O, Beaudart C, Buckinx F, Bruyère O, Reginster JY (2017) The future prevalence of Sarcopenia in Europe: a claim for public health action. Calcif Tissue Int 100(3):229–234. https://doi.org/10.1007/s00223-016-0220-9
3. Eaton M (2015) Evolutionary humanoid robotics. https://doi.org/10.1007/978-3-662-44599-0
4. Brooks RA, Aryananda L, Edsinger A, Fitzpatrick P, Kemp C, O'Reilly U-M et al (2004) Sensing and manipulating built-for-human environments. Int J Humanoid Rob 1(01):1–28
5. Mori M, MacDorman KF (2012) The Uncanny Valley [From the Field]. IEEE Rob Autom Mag 19(2):98–100. https://doi.org/10.1109/MRA.2012.2192811

6. Kajita S, Hirukawa H, Harada K, Yokoi K (2014) Introduction to humanoid robotics. Retrieved from https://www.springer.com/us/book/9783642545351
7. Valentí Soler M, Agüera-Ortiz L, Olazarán Rodríguez J, Mendoza Rebolledo C, Pérez Muñoz A, Rodríguez Pérez I, ... Martínez Martín P (2015) Social robots in advanced dementia. Front Aging Neurosci 7. https://doi.org/10.3389/fnagi.2015.00133
8. Martinez-Martin E, del Pobil AP (2018) Personal robot assistants for elderly care: an overview. In Costa A, Julian V, Novais P (eds) Personal assistants: emerging computational technologies, pp. 77–91. https://doi.org/10.1007/978-3-319-62530-0_5
9. Oberman LM, McCleery JP, Ramachandran VS, Pineda JA (2007) EEG evidence for mirror neuron activity during the observation of human and robot actions: toward an analysis of the human qualities of interactive robots. Neurocomputing 70(13):2194–2203. https://doi.org/10.1016/j.neucom.2006.02.024
10. Giannopulu I, Terada K, Watanabe T (2018) Communication using robots: a perceptionaction scenario in moderate ASD. J Exp Theor Artif Intell 30(5), 603–613. https://doi.org/10.1080/0952813X.2018.1430865
11. Damiani P, Grimaldi R, Palmieri S (2013) Robotica educativa e aspetti non verbali nei Disturbi Specifici di Apprendimento. 1:1211–1220. Retrieved from https://iris.unito.it/handle/2318/134850#.XG_jvOhKjOg